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Distributed Clustering based Energy Efficient Routing Algorithm for Heterogeneous Wireless Sensor Networks

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Abstract

In wireless sensor networks, clustering is the dominantly used technique for energy efficient routing protocols. Clustering increases the scalability and lifetime of WSN. Many clustering based energy efficient algorithms were proposed like LEACH, M-LEACH, BLEACH, etc. These algorithms need additional energy to process cluster head changes and cluster heads are not uniformly distributed. Hence a distributed energy efficient protocol is proposed which selects cluster-heads based on probability ratio between initial energy of each node and average energy of the network. In the proposed method, the chance of becoming cluster head is based on having highest initial and residual energy. Experimental results show that the proposed method increases the life time of the network than traditional method in heterogeneous wireless sensor environments.

Keywords: Clustering Schemes, Energy Efficient Protocols, Heterogeneous WSN, LEACH, Lifetime of WSN, WSN

1. Introduction

With a rapid development in hardware technology, usage of low powered sensors has increased. These tiny sensors are wireless in nature, capable of sensing the environment and communicating these information to central authority for further processing[1]. Hence a wireless sensor network, abbreviated as WSN in network domain, is a group of lightweight, small, portable sensor nodes that has been deployed to monitor assets, battle fields, transportation traffic, environments, etc. WSN can scale from tens to thousands of sensor nodes[1]. To achieve high degree of accuracy, these sensor nodes are randomly deployed in the interested area or very close to it.

One of the components of a sensor node is the power source which supplies energy needed by the sensor to carryout already programmed task. The power source contains battery with limited energy. These tiny sensors cannot be recharged after deployment[2]. Sensors use this small energy to capture, process, store and communicate the data with fellow sensors as well as with central authority. Hence it is very important to conserve the sensor energy and use it in an effective manner. Moreover, the performance of a WSN is dependent on the lifetime of the sensor nodes[3].

Various energy efficiency techniques were proposed that can prolong the battery of a sensor. Grouping the sensors to form clusters, locating a head among various cluster members so that Cluster Head (CH) alone can communicate with the sink node (base station) is the best idea[4]. The method reduces the battery usage of sensor node a large. Clustering technique also performs data

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aggregation that compress the actual data to a small set of meaningful information. Selection of cluster heads can be done randomly or by following certain predefined protocols. However, cluster head selection is having large impact on WSN's energy.

In this paper, an energy efficient adaptive clustering algorithm for multihop heterogeneous wireless sensor network is presented which improves the performance of WSN by minimizing energy consumption of nodes. The proposed method also allows inter and intra communication among sensors.

2. Background

Generally numerous sensors are deployed to monitor the environment for accurate data in an adhoc manner. These sensors may have uniform properties, defining the homogeneity, called as homogeneous WSNs. If these sensors vary in cost, storage, communication methods, sensing style, computational differences, energy capabilities, etc. they are said to be heterogeneous WSNs[5]. The deployment of heterogeneous wireless sensor networks are much complicated than homogeneous WSNs. In heterogeneous WSN, network topology and functionalities are different. More complex hardware is used in heterogeneous WSN to embed cluster heads.

Generally heterogeneous WSN adopts multiple hopping techniques to reach the cluster head. In WSN environments, need of power increases in square metrics as the distance between source and destination increases[6]. If the distance between source and destination nodes in WSN is R, then the power required for single hop transmission between source and destination is R2. This power consumption can be minimized if transmission is done in multiple hops.

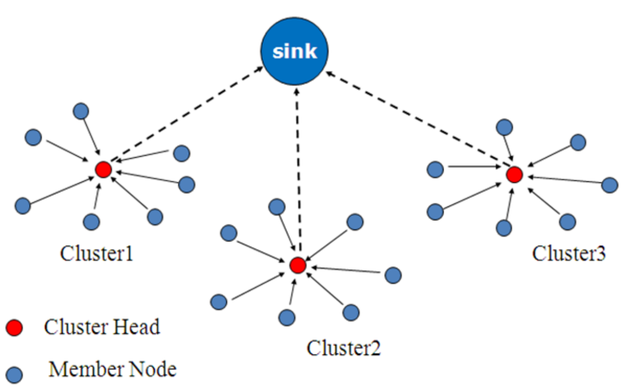

Figure 1. WSN.

Cluster heads need more energy as they have to aggregate the received data and perform long-range transmission to the sink node[7]. It is easy to configure clustering algorithm for homogeneous WSNs. Clustering algorithms in heterogeneous WSNs are difficult to device due to its complicated energy configuration and network operation. There are several algorithms proposed for clustering in heterogeneous WSNs.

Yin Ying Yang and Mihaela Cardei[8] presented delay-constrained energy efficient routing in heterogeneous WSNs. The proposed method supports periodic and event-based reporting applications by using static sensor nodes, mobile and static super nodes. The algorithm satisfies delay requirement for different types of data messages. The source sensor node selects the best relay super node from its routing table and sends the message. The super node transmits the message to the sink node.

Dilip Kumar, et al.[9] proposed energy efficient heterogeneous clustered scheme for wireless sensor networks. By using different weighted probability, cluster heads are elected in this algorithm. As usual, fellow sensor nodes communicate to the cluster heads and cluster head aggregates the data and transmits to the base station. Communication between cluster head and sink node happens via single-hop fashion. Three types of sensor nodes are used in proposed method viz. type-3, type-2 and type-1 with more battery energy in type-3 and type-2 than type-1.

Elbhiri, et al.[10] presented distributed energy efficient clustering scheme for heterogeneous wireless sensor networks. This method uses dynamic changing with more efficiency in cluster head selection probability. Cluster head is defined by initial and residual energy level and estimates network lifetime to compute reference energy. In this method, cluster head directly collects message from nodes and transmits aggregated data to the base station.

Marin-Perianu, et al.[11] energy efficient service discovery protocol for heterogeneous wireless sensor networks. Here each node is identified with hardware identifier, which is unique along with capability grades. The node with higher capability grade becomes cluster head and collects, aggregates data from other sensor nodes. This scheme provides low construction and maintenance overhead, and reacts quickly to the topological changes in sensor network. This change is based on decisions of one hop neighbourhood information and avoids chain reaction problems. This scheme depends on a clustering structure which offers storage of service descriptions.

Parul Saini and Ajay K Sharma[12] proposed energy efficient clustering protocol for prolonging the life time of nodes in heterogeneous wireless sensor networks. This is the extension of DEEC (Distributed Energy Efficient Clustering) and selects cluster heads from high energy nodes thereby increasing life time of network. By modifying the threshold value of a node, cluster head is selected. Multiple cluster heads are randomly selected within a large number of nodes with expanded area, additional energy loss occurs and localization energy is approximately proportional to number of SYN packets received between the nodes.

Jian Peng, et al.[13] proposed energy-efficient prediction clustering algorithm for multilevel heterogeneous wireless sensor networks. The proposed prediction clustering algorithm is adaptive and fellow nodes select the cluster head using factors such as energy, communication cost. The node with higher residual energy is having higher probability to be elected as cluster head. By this way, the network energy can be dissipated uniformly. An energy consumption prediction model is used which reduces energy consumption and prolong network life time. The proposed algorithm achieves longer sensor network life time, higher energy efficiency with great network monitoring quality.

All the above protocols contain merits as well as demerits. LEACH protocol works by electing the cluster head according to the energy left in each node. But it requires assistance protocol to know the total energy left in the network. Variation of LEACH protocol called M-LEACH[14] provides multi-hop routing within each cluster and only powerful nodes can become cluster heads. Another variant called B-LEACH elects the cluster head according to the dissipated energy. This method is adaptive and highly energy efficient. Above variations of LEACH protocol triggered us the idea to develop adaptive, multi-hop, energy efficient clustering protocol for heterogeneous WSNs which is presented in this paper.

3. Heterogeneous Network Model

Heterogeneous wireless sensor networks mainly vary in three resources such as computational, link and energy. The impact of heterogeneity is measured with response time and life time of a network[15]. The performance measures for the heterogeneous WSNs are network life time, number of cluster heads per round, number of sensor nodes per round and throughput. The basic assumption of a heterogeneous network model is that the network is located in M x M square area where M stands for number of sensor nodes randomly distributed within the network.

The nodes can be slightly mobile or stationery and sink node is placed in the middle area. Cluster heads execute fusion function to reduce correlated data. The cluster head aggregates the sensor's data and transmit to the sink node. Two types of sensors are found in two-level heterogeneous networks. They are advanced nodes and normal nodes[16]. Let E_0 be the initial energy in normal nodes and 'a' be the additional energy available in advanced nodes. Let N_m advanced nodes equipped with initial energy as E_0 (1 + a). The total initial energy available in two-level heterogeneous WSN is given by the below Equation.

$$E = N\,(1 = m)\,E_O + N_m\,E_O\,(1 + \alpha) = NE_O\,(1 + \alpha_m)$$

The above equation can be modified for multi-level heterogeneous networks. Let initial energy of sensor node as $[E_0, E_0(1 + a_{max})]$ with E0 as lower level energy and a_{max} as higher level energy. The total initial energy available in multi-level heterogeneous WSN is given by

$$E = \sum_{i=1}^{N}[E_0(a + a_i)] = \sum_{0}\left(N + \sum_{i=1}^{N} a_i\right)$$

In multi-level heterogeneous WSNs, a node is equipped with a_i times more energy than lower bound level E_0.

4. Proposed Method

The first work of heterogeneous WSN is to select the cluster head. Our proposed method uses initial and residual energy for selecting cluster heads. Our method estimates the ideal-value for network life time. Cluster head is selected based on residual energy of nodes. Let 'r' be the number of rounds a node can become a cluster head. Let P = 1/r be the average probability for a node to become cluster head in 'r' rounds. Let $\overline{E}(r)$ represents the average energy at round 'r' of the network, which is computed by

$$\bar{E}(r) = \frac{1}{N}\sum_{i=1}^{N} E_i(r)$$

The average total number of cluster heads per round is equivalent to

$$\sum_{i=1}^{N} P_i = \sum_{i=1}^{N} P_{opt}\frac{E_i(r)}{\bar{E}(r)} = P_{opt}\sum_{i=1}^{N} P_{opt}\frac{E_i(r)}{\bar{E}(r)} = NP_{opt}$$

Where P_{opt} is the rotation period to become cluster head. By using the above value each node determines whether it can become a cluster head in that round or not. The above equation is slightly modified for two-level heterogeneous networks. Here each node contains different initial energy. The probability to become cluster head for advanced nodes is given by

$$P_{adv} = \frac{P_{opt}}{1+a_m}$$

and for normal nodes.

$$P_{nrm} = \frac{P_{opt}(1+a)}{(1+a_m)}$$

Then the weighted probability is given by the Equation

$$P_w = \frac{P_{opt}N(1+a_i)}{(N+\sum_{i=1}^{N} a_i)}$$

5. Results and Discussion

In this section, we provide the performance of our proposed method. The simulation parameters used for our method is listed below:

Number of nodes in the network 100
Energy required to transmit
Data to a short distance 10Pj / bit / m^2
Energy required to transmit
Data to a long distance 0.0013Pj / bit / m^4
Energy consumed to forward
A received data 50nj / bit
Data aggregation energy 5nj / bit.

In order to evaluate the performance of our proposed method, a heterogeneous WSN of 100 M x 100 M dimension is simulated. The advanced and normal sensor nodes are randomly deployed in the network, with horizontal and vertical coordinates of each sensor node are randomly selected between 0 to maximum dimension value. The maximum distance between any sensor node in the network and sink is 70 M approximately. For performance comparison, LEACH, M-LEACH and B-LEACH protocols are used. The Table 1 shows the simulation results.

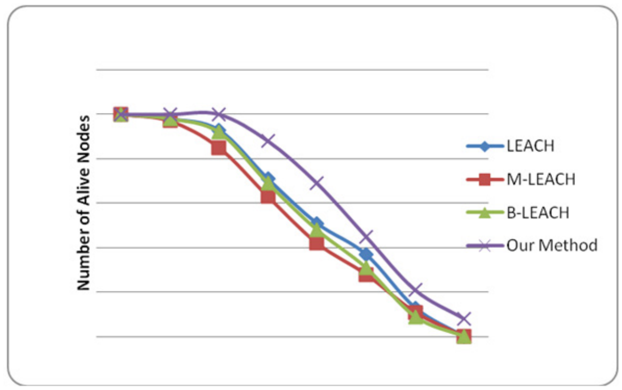

Figure 2. Number of alive nodes vs. number of rounds..

Above Table and graph represents the life period of nodes at various levels of rounds in the network. All the protocols which are considered for performance comparison with our method, performs same like our method up to 1000 rounds. After that, the difference in number of alive node varies. The reduction in number of alive nodes is huge from 2500 rounds. During 4000th round, all the nodes in the traditional methods die and 8 nodes are alive in our method. From this, it is clear that the proposed method performs better in terms of number of alive nodes.

The second simulation relates to the number of packets received by the base station. This communication is between cluster heads and sink node during the life time of network. The Table 2 provides the performance

Table 1. Number of alive nodes for different rounds

Method	Number of rounds							
	500	1000	1500	2000	2500	3000	3500	4000
LEACH	100	98	93	71	51	37	13	00
M-LEACH	100	97	85	63	42	28	11	00
B-LEACH	100	98	92	69	48	31	09	00
Our Method	100	100	100	88	69	45	21	08

results of our proposed method along with the traditional methods.

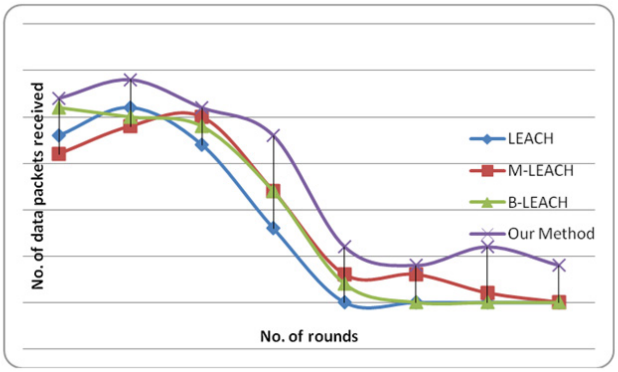

Figure 3. Number of packets transmitted vs. number of rounds.

From the above simulation results, it is clear that our proposed method continuously sends the data packet to the sink node up to 4000 rounds where as traditional methods fail to transmit at the end of 3000 rounds. This simulation result exhibit the life time of network and it is evident that our method elongates the life time of network after 4000 rounds.

The third and final experiment conducted is to find the number of clusters formed during each round. This test ensures that the proposed system supports heterogeneity. The Table 3 and graph represents the results with respect to number of clusters formed.

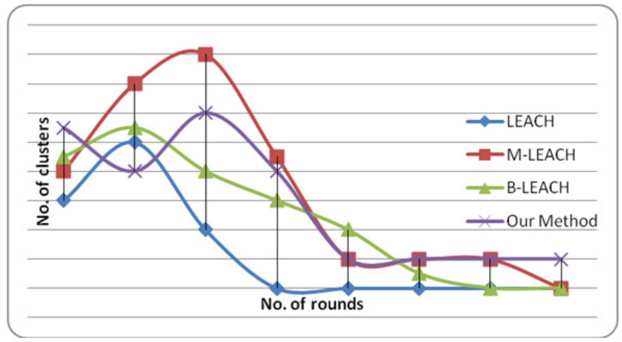

Figure 4. Number of clusters formed vs. number of rounds.

As our proposed method contains super nodes and normal nodes, the stable region has increased significantly. The weighted probability to elect cluster head needs energy of each node to be consumed in proportion to the node's initial energy.

6. Conclusion

In this paper, clustering based energy conservation protocol for heterogeneous WSN is proposed. The simulation results of the proposed method are compared with traditional energy efficient schemes viz. LEACH, M-LEACH, B-LEACH, etc. The comparison is based on three heterogeneity parameters such as number of alive nodes, number of data packets transmitted and number

Table 2. Number of packets transmitted for different rounds

Method	Number of rounds							
	500	1000	1500	2000	2500	3000	3500	4000
LEACH	18	21	17	08	00	00	00	00
M-LEACH	16	19	20	12	03	03	01	00
B-LEACH	21	20	19	12	02	00	00	00
Our Method	22	24	21	18	06	04	06	04

Table 3. Number of cluster heads formed for different rounds

Method	Number of rounds							
	500	1000	1500	2000	2500	3000	3500	4000
LEACH	06	10	04	00	00	00	00	00
M-LEACH	08	14	16	09	02	02	02	00
B-LEACH	09	11	08	06	04	01	00	00
Our Method	11	08	12	08	02	02	02	02

of clusters formed. Simulation result shows that the proposed method elongates the lifetime of WSN by nearly more than 13% when compared to traditional methods. Therefore, the proposed method is good in terms of life time and reliability.

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